

Causes and Effects of Soil Acidity



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Soil acidity is a crop production problem of increasing concern in central and western Oklahoma. Although acid soil conditions are more widespread in eastern Oklahoma, the more natural occurrence there has resulted in farm operators being better able to manage soil acidity in that part of the state. However, in central and western Oklahoma the problem appears to grow with time. This fact sheet explains why soils become acid and the problems acid soils create for crop production. OSU Extension Facts No. 2229 explains how soil acidity and the lime requirement are determined by soil testing. A subsequent fact sheet discusses managing wheatland soils in Oklahoma. (see Extension Facts No. 2240)

Why Soils are Acid

The four major causes for soils to become acid are listed below:

1. Rainfall and leaching
2. Acidic parent material
3. Organic matter decay
4. Harvest of high yielding crops

The above causes of soil acidity are more easily understood when we consider that a soil is acid when there is an abundance of acidic cations (pronounced cat-eye-on), like hydrogen (H^+) and aluminum (Al^{+++}) present compared to the alkaline cations like calcium (Ca^{++}), magnesium (Mg^{++}), potassium (K^+), and sodium (Na^+).

Rainfall and Leaching

Excessive rainfall is an effective agent for removing basic cations over a long time period (thousands of years). In Oklahoma, for example, we can generally conclude that soils are naturally acidic if the rainfall is above 30 inches per year. Therefore, soils east of I-35 tend to be acidic and those west of I-35, alkaline. There are many exceptions to this rule though, mostly as a result of item 4, intensive crop production. Rainfall is most effective in causing soils to become acidic if a lot of water moves through the soil rapidly. Sandy soils are often the first to become acidic because water perco-

lates rapidly, and sandy soils contain only a small reservoir of bases (buffer capacity) due to low clay and organic matter contents. Since the effect of rainfall on acid soil development is very slow, it may take hundreds of years for new parent material to become acidic under high rainfall.

Parent Material

Due to differences in chemical composition of parent materials, soils will become acidic after different lengths of time. Thus, soils that developed from granite material are likely to be more acidic than soils developed from calcareous shale or limestone.

Organic Matter Decay

Decaying organic matter produces H^+ which is responsible for acidity. The carbon dioxide (CO_2) produced by decaying organic matter reacts with water in the soil to form a weak acid called carbonic acid. This is the same acid that develops when CO_2 in the atmosphere reacts with rain to form acid rain naturally. Several organic acids are also produced by decaying organic matter, but they are also weak acids. Like rainfall, the contribution to acid soil development by decaying organic matter is generally very small, and it would only be the accumulated effects of many years that might ever be measured in a field.

Crop Production

Harvesting of crops has its affect on soil acidity development because crops absorb the lime-like elements, as cations, for their nutrition. When these crops are harvested and the yield is removed from the field, then some of the basic material responsible for counteracting the acidity developed by other processes is lost, and the net affect is increased soil acidity. Increasing crop yields will cause greater amounts of basic material to be removed. Grain contains less basic materials than leaves or stems. For this reason, soil acidity will develop faster under continuous wheat pasture than when grain only is harvested. High yielding forages, such as bermudagrass or alfalfa, can cause soil acidity to develop faster than with other crops.

Table 1 identifies the approximate amount of lime-

like elements removed from the soil by a 30 bushel wheat crop. Note that there is almost four times as much lime material removed in the forage as the grain. This explains why wheat pasture that is grazed out will become acidic much faster than when grain alone is produced. Using 50 percent ECCE lime, it would take about one ton every 10 years to maintain soil pH when straw (or forage) and grain are produced annually at the 30 bushel per acre level.

The use of fertilizers, especially those supplying nitrogen, has often been blamed as a cause of soil acidity. Although acidity is produced when ammonium containing materials are transformed to nitrate in the soil, this is countered by other reactions and the final crop removal of nitrogen in a form similar to that in the fertilizer. The affect of nitrogen fertilizers has been to increase yields and thus increase the removal of bases as shown in Table 1.

Table 1. Bases removed by a 30 bushel wheat crop

	Calcium	Potassium	Magnesium	Sodium	Total
	Pounds ECCE lime				
Grain	2	10	10	2	24
Straw*	11	45	14	9	79
Total	13	55	24	11	103**

* Straw/forage

** One ton of alfalfa will remove slightly more than this amount.

What Happens in Acid Soils

Knowing the soil pH helps identify the kinds of chemical reactions that are likely to be taking place in the soil. Generally, the most important reactions from the standpoint of crop production are those dealing with solubilities of compounds or materials in soils. In this regard, we are most concerned with the affects of pH on the availability of toxic elements and nutrient elements.

Toxic elements like aluminum and manganese are the major causes for crop failure in acid soils. These elements are a problem in acid soils because they are more soluble at low pH. In other words, more of the solid form of these elements will dissolve in water when the pH is acid. There is always a lot of aluminum present in soils because it is a part of most clay particles.

Element Toxicities

When the soil pH is above about 5.5, the aluminum in soils remains in a solid combination with other ele-

ments and is not harmful to plants. As the pH drops below 5.5, aluminum containing materials began to dissolve. Because of its nature as a cation (Al^{+++}), the amount of dissolved aluminum is 1000 times greater at pH 4.5 than at 5.5, and 1000 times greater at 3.5 than at 4.5. For this reason, some crops may seem to do very well, but then fail completely with just a small change in soil pH. Wheat, for example, may do well even at pH 5.0, but usually will fail completely at a pH of 4.0.

The relationship between pH and dissolved manganese in the soil is similar to that just described for aluminum, except that manganese (Mn^{++}) only increases 100 fold when the pH drops from 5.0 to 4.0.

Toxic levels of aluminum harm the crop by "root pruning." That is, a small amount of aluminum in the soil solution in excess of what is normal causes the roots of most plants to either deteriorate or stop growing. As a result, the plants are unable to absorb water and nutrients normally and will appear stunted and exhibit nutrient deficiency symptoms, especially those for phosphorus. The final affect is either complete crop failure or significant yield loss. Often the field will appear to be under greater stress from pests, such as weeds, because of the poor condition of the crop and its inability to compete.

Toxic levels of manganese interfere with the normal growth processes of the above ground plant parts. This usually results in stunted, discolored growth and poor yields.

Desirable pH

The adverse effect of these toxic elements is most easily (and economically) eliminated by liming the soil. Liming raises the soil pH and causes the aluminum and manganese to go from the soil solution back into solid (non-toxic) chemical forms. For grasses, raising the pH to 5.5 will generally restore normal yields. Legumes, on the other hand, do best in a calcium rich environment and often need the pH in a range of 6.5 to 7.0 for maximum yields.

A soil pH in the range of 6.0 to 7.0 is also desirable from the standpoint of optimum nutrient availability. However, the most common nutrient deficiencies in Oklahoma are for nitrogen, phosphorus and potassium, and availability of these elements will not be greatly changed by liming. Nutrients most affected by soil pH are iron and molybdenum. Iron deficiency is more likely to occur in non-acid (high pH) soils. Molybdenum deficiency is not common in Oklahoma, but would be most apt to occur in acid soils and could be corrected by liming.